TACCIMO
Template for Assessing Climate Change Impacts and Management Options

TACCIMO Literature Report

Literature Report – Annotated Bibliography Format
Report Date: May 3, 2013

Content Selections:
FACTORS – Recreation, Land Use & Planning
CATEGORIES – General Impacts, Hunting and Fishing, Interactions with other Factors, Quality of Recreations Experience, Water Recreation, Road and Facility Planning
REGIONS – National, East, R9: Eastern, North Atlantic, R8: Southern, South Atlantic, South Central

How to cite the information contained within this report

Each source found within the TACICMO literature report should be cited individually. APA 6th edition formatted citations are given for each source. The use of TACCIMO may be recognized using the following acknowledgement:

"*We acknowledge the Template for Assessing Climate Change Impacts and Management Options (TACCIMO) for its role in making available their database of climate change science. Support of this database is provided by the Eastern Forest Environmental Threat Assessment Center, USDA Forest Service.*"

Best available scientific information justification

Content in this Literature report is based on peer reviewed literature available and reviewed as of the date of this report. The inclusion of information in TACCIMO is performed following documented methods and criteria designed to ensure scientific credibility. This information reflects a comprehensive literature review process concentrating on focal resources within the geographic areas of interest.

Suggested next steps

TACCIMO provides information to support the initial phase of a more comprehensive and rigorous evaluation of climate change within a broader science assessment and decision support framework. Possible next steps include:

1. Highlighting key sources and excerpts
2. Reviewing primary sources where needed
3. Consulting with local experts
4. Summarizing excerpts within a broader context

More information can be found in the user guide. The section entitled Content Guidance provides a detailed explanation of the purpose, strengths, limitations, and intended applications of the provided information.

Where this document goes

The TACCIMO literature report may be appropriate as an appendix to the main document or may simply be included in the administrative record.

Brief content methods

Content in the Literature Reports is the product of a rigorous literature review process focused on cataloguing sources describing the effects of climate change on natural resources and adaptive management options to use in the face of climate change. Excerpts are selected from the body of the source papers to capture key points, focusing on the results and discussions sections and those results that are most pertinent to land managers and natural resource planners. Both primary effects (e.g., increasing temperatures and changing precipitation patterns) and secondary effects (e.g., impacts of high temperatures on biological communities) are considered. Guidelines and other background information are documented in the user guide. The section entitled Content Production System fully explains methods and criteria for the inclusion of content in TACCIMO.

TABLE OF CONTENTS

Effects by Source

Thursday, May 02, 2013

RESOURCE AREA (FACTOR): RECREATION

GENERAL IMPACTS

NATIONAL

Amelung, B., Nicholls, S., & Viner, D. (2007). Implications of global climate change for tourism flows and seasonality. Journal of Travel Research, 45(3), 285-296. doi: 10.1177/0047287506295937

"Climate change may lead to changes in climatic seasonality. This is crucial, because time is of the essence in tourism. To give an example: for many people, school holidays represent the "window of opportunity" for planning holiday activities. The demand models discussed above assume temporal indifference among tourists, which may be an important cause of their low estimates of the effects that climate change will have on the tourist industry, relative to factors such as economic development and population growth (Hamilton, Maddison, and Tol 2005)."

"Figures 2 and 3 (in text) illustrate global TCI [tourism climatic index] values for June, July, and August for the 2050s under the A1F and B1A scenarios, respectively. They suggest a definite poleward shift in the zones of maximum tourism comfort as compared to the historical (1970s) period, although this shift is less dramatic under the B1A scenario than the A1F, as anticipated."

"Figures 2-4 (on the Web) illustrate global TCI [tourism climatic index] values for June, July, and August for the 2020s, 2050s, and 2080s, respectively, under the A1F scenario. As a series, they suggest a pronounced poleward movement in tourism comfort as time progresses, such that, by the 2080s, the most ideal conditions for tourism activity in the northern hemisphere will have shifted to the countries of northern Europe and Canada. Similarly, the band of tourism comfort in the southern hemisphere is projected to move southwards."

"Figures 5-7 (Web) illustrate global TCI [tourism climatic index] values for June, July, and August for the 2020s, 2050s, and 2080s, respectively, under the B1A scenario. Given the nature of this scenario, the less dramatic poleward shift in comfort zones as compared to that under the A1F scenario is as expected. Nevertheless, even this scenario does suggest that, by the 2080s, the most comfortable regions for summer tourism in the northern hemisphere will have shifted from the Mediterranean coastlines of Spain, France, Italy, Greece, and Turkey to include northern France, southern parts of the United Kingdom, Germany, the Low Countries, and southern Scandinavia. Similarly, the most comfortable regions of North America are projected to have shifted northwards, with the concomitant reverse, a southwards shift, in the southern hemisphere."

"Projections of climate change suggest that the band of areas offering extremely low levels of tourist comfort associated with the equator is likely to widen as time progresses, such that by the 2080s, very few locations in Central America, the northern part of South America, the central band of Africa, or Southeast Asia will offer even a single month in which conditions are likely to be comfortable for general tourist activity."

Joyce, L. A., Blate, G. M., Littell, J. S., McNulty, S. G., Millar, C. I., Moser, S. C., . . . Peterson, D. L. (2008). National forests. in: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. a report by the U.S. climate change science program and the subcommittee on global change research. U.S.Environmental Protection Agency, 1-127.

"Because individual recreational opportunities are often a function of climate (cold-water fisheries or winter snow), climate change may affect both the opportunity to recreate and the quality of recreation (Irland et al., 2001), curtailing some recreational opportunities and expanding others."

"Climate change may also increase recreational opportunities: Fewer cold days, for example, may encourage more hiking, biking, off-road vehicle use, photography, swimming, and other warm-weather activities."

"Recreational opportunities may be curtailed if forest managers decide (for public safety or resource conservation reasons) to reduce access during and in the wake of major disturbances such as fire, droughts, insect outbreaks, blowdowns, and floods, all of which are projected to increase in frequency and severity during the coming decades (IPCC, 2007)."

Prideaux, B., Coghlan, A., & McNamara, K. (2010). Assessing tourists' perceptions of climate change on mountain landscapes. Tourism Recreation Research, 35(2), 187-199.

"Commenting on the possible impacts of climate change, a number of authors (Matzarakis 2002; Braun et al. 1999) and reports (UNTWO 2007) have noted that the impacts are likely to be severe and long-lasting. It is also likely that the impacts will generate large-scale disturbances in many tourism markets (Prideaux et al. 2009; Gossling and Scott 2008; Gossling and Svensson 2006; Hamilton et al. 2005; Loman-Scalon 2006), particularly those that rely on distant generating markets (Dwyer and Forsyth 2008; Simmons and Becken 2004)."

"On a destination scale, the impact of climate change is likely to cause substantial changes to local ecosystems (Walther et al. 2002) and as these changes occur the amenity of particular regions for tourism use is likely to change. Impacts may be described under four categories: changes to local ecosystems; changes to local weather patterns defined as the daily and annual pattern of precipitation, wind and humidly; changes in human use, activity and consumption as weather patterns change local ecosystems; and finally, economic impacts that can be measured as impacts to the regional economy and effects on ecosystem services (Stern 2006)."

Ramasamy, R., Swamy A. (2012). Global Warming, Climate Change and Tourism: A Review of Literature. Revista de Cultura e Turismo, 6, 72-98.

"With the onslaught of melting ice at the earth’s poles, oceans will rise causing many Island beach resorts to be covered in water according to [tourism-climate change] modeling scenarios."

"Models [of how tourism would be affected by climate change] showed there would be a shifting of tourists to other areas due to rain, temperatures, and snow. Beaches would erode and no longer be a destination; ski areas would not have snow and therefore fewer ski destinations would be available; wetlands would take over current dry lands and change the destination attributes."

"The model [econometric simulation model of international tourist flows, Hamilton & R. 2007] showed that climate change in countries at higher latitudes and altitudes will become more attractive to tourists, both domestic tourists and those from abroad. Tourists from the north west of Europe currently dominate international tourism—the Germans, the Irish and the British together account for 25% of the international tourist market—which implies that the world total of international tourist numbers initially falls because of climate change. The model also showed that the effect of climate change is much smaller than the combined effects of population and economic growth, at least for most countries."

"Results [of Jones & Scott 2006] indicate that Canada's national parks could experience an increase in visitors under climate change due to a lengthened and improved warm-weather tourism season. In the 2020s, overall visitation levels were projected to increase 6% to 8%, with [the] number of parks projected to experience larger increases (+12% to 30%). The largest increase in visitation occurs during the spring and fall months [Jones & Scott 2006]."

"The analysis of this paper [Lise & R. 2002] leads to the conclusion that climate is an important consideration for tourists' choice of destination. A gradual warming would thus induce tourists to seek different holiday destinations or travel at different times during the year. Climate change is therefore likely to lead to drastic changes in tourist behavior."

"The paper [Matzarakis 2006] also cautions that emission scenarios in tourism destinations will suffer from bioclimatic change conditions and this will have a significant impact on local economies in the near future."

"Certain areas will be affected more by climate change than other areas including mountains (lack of snow), islands and beaches (higher water levels and erosion), warm climates getting too hot, and cold climates warming up. This, in turn, changes the types of tourism such as snow skiing, beach recreation, and hiking, while possibly eliminating some recreation, such as snowmobiling."

"First, visitor numbers [to tourist locations] will likely increase in the northern part of the northern hemisphere and the southern part of the southern hemisphere [due to climate change]. Additionally, [tourist] destination seasonality will affect length of visitation. Ski areas will shrink in their season, but mountain tourism in the fall and spring will lengthen."

Scott, D., McBoyle, G., & Schwartzentruber, M. (2004). Climate change and the distribution of climatic resources for tourism in North America. Climate Research, 105-

"Weather and climate are key influences on the tourism sector worldwide (Smith 1993, Boniface & Cooper 1994, Perry 1997), affecting the length and quality of tourism seasons and the environmental resources that draw tourists to destinations (e.g. health of coral reefs for diving, water levels for boating, and snow cover for skiing). A 1°C warmer than average summer season was found to increase domestic tourism expenditures in Canada by 4% (Wilton & Wirjanto 1998)."

Yu, G., Schwartz, Z., and Walsh, J. (2009). A weather-resolving index for assessing the impact of climate change on tourism related climate resources. Climatic Change, 95(3-4):551-573. doi:10.1007/s10584-009-9565-7

"In particular, a changing climate pattern can create both new constraints and new opportunities for tourism-related outdoor recreation (Scott et al. 2005; UNWTO 2007; Becken and Hay 2007; Scott and McBoyle 2007). For example, it was suggested that low-altitude ski resorts face economic challenges due to less snowfall and shorter skiing seasons (Koenig and Abegg 1997; Scott et al. 2006; OECD 2006), while arctic regions will stand to gain as their summer season is likely to be lengthened (Pagnan 2003)."

"Climate is one important factor that causes the seasonality of tourism, as does the school holiday schedule. Climate change is likely to change tourism seasonal pattern in the long run."

R8: SOUTHERN

Scott, D., McBoyle, G., & Schwartzentruber, M. (2004). Climate change and the distribution of climatic resources for tourism in North America. Climate Research, 105-

"With additional cities gaining climates suitable for winter sun vacations, there will be increased destination choice and competition for the short-term winter sun holiday and the seasonal 'snowbird' market. This would present new opportunities in some regions (e.g. Georgia and South Carolina), while potentially reducing the market share of leading current destinations such as southern Florida, Arizona and particularly Mexico."

SOUTH ATLANTIC

Yu, G., Schwartz, Z., and Walsh, J. (2009). A weather-resolving index for assessing the impact of climate change on tourism related climate resources. Climatic Change, 95(3-4):551-573. doi:10.1007/s10584-009-9565-7

"For Orlando [Florida], while the influence of global warming on the quality of tourism climate conditions is negative overall (cf. the "annual" column in Table 5), there are substantial differences among seasons. Tourism conditions can be expected to deteriorate in summer, but to become more favorable in some winter months."

EAST

Najjar, R. G., Walker, H. A., Anderson, P. J., Barron, E. J., Bord, R. J., Gibson, J. R., Kennedy, V. S., … & Swanson, R. S. (2000). The potential impacts of climate change on the mid-Atlantic coastal region. Climate Research, 14, 219-233.

"The only positive societal benefit is the potential for increased coastal tourism due to the warmer climate. Table 3 also presents the potential impacts on the MAC [mid-Atlantic coastal] region of future population growth. These impacts tend to be in the same direction as the climate change impacts."

HERITAGE RESOURCES

NATIONAL

Berenfeld, M. L. (2008). Climate Change and Cultural Heritage: Local Evidence, Global Responses. The George Wright Forum, 25(2), 66-82.

"The third category—those sites that can be protected [from climate change impacts] through strategic planning and interventions—is the largest and the most complex [compared to sites that are doomed and sites that are so important that we are willing to save them at almost any cost]. It includes the many sites around the world that require conservation and protection for many of the usual reasons — neglect, lack of resources, exposure, old age—but which will suffer more dramatically as a result of climate change. "

Maldonado, J. K., Shearer, C., Bronen, R., Peterson, K., & Lazrus, H. (2013). The impact of climate change on tribal communities in the US: displacement, relocation, and human rights. Climatic Change, 1-14. doi:10.1007/s10584-013-0746-z

"Entire tribal communities in Alaska, Louisiana, and the Pacific Islands, among others, are being forced to relocate due to accelerated sea level rise, erosion, extreme weather events, and/or permafrost thaw, as well as a lack of resources to cope with these impacts in-situ (Callaway et al. 1999; McLean et al. 2009; Louisiana Workshop 2012). In the United States, as well as globally, communities facing the likelihood of relocation are also often those that have experienced systemic impoverishment and injustice, such as coastal tribes of Alaska and Louisiana. This holds significant human rights implications, as tribal communities are among those that are least responsible for causing climate change, are often subject to harm by powerful forces such as oil companies that are responsible for proliferating climate change, and their lands, resources, and culture stand in direct threat or being lost or severely diminished due to climate change impacts (Oliver-Smith 2011:162; UN 2007). Climate-induced displacement does not only sever the physical ties and rights indigenous peoples have to their land and resources, but also the spiritual relationship they have with their traditionally-occupied places (UN 2007)."

"In the contiguous 48 states, tribes experience increased vulnerability to changing weather patterns and climate impacts due to loss of traditional subsistence practices resulting from the history of reservations and western land expansion. As opposed to how Natives once moved from place to place as needed for food and safety, those on reservations have limited options because of restrictive reservation boundaries (Lynn et al. 2013), similar to the populations of low-lying island countries that are constrained by geographic and political boundaries (Lazrus 2012). Federal laws obstruct expanding or transferring tribal jurisdiction and few tribes have the economic means to buy new land. Therefore, tribes' traditional cultures are directly threatened by current and future climate change impacts (Houser et al. 2001:357). For coastal communities, there is now the added complication that many coastlines are destabilizing from erosion, sea level rise, and/or permafrost thaw, further limiting their relocation options and complicating their dependence on living near water to meet subsistence needs."

"Climate-induced displacement is bringing new challenges that are particularly affecting tribal populations, as these three case studies [in Alaska, Louisiana, and the Pacific Islands] illustrate. Yet while anthropogenic climate change may be a relatively new problem, many of the issues it is raising around displacement and relocation are not without precedent. That is why we have used the case studies to examine the implications for policymakers, while also drawing upon lessons learned from development-forced displacement and resettlement and past US efforts toward relocation. Further, tribal communities have a long history of adapting to environmental changes that should be recognized and protected. We therefore argue these efforts should be rooted in a human rights framework that asserts and protects tribal rights to determination and preservation, which could serve as both a national and international model for future displacements. Indeed, traditional tribal methods for adaptation could be used as a basis for informing and enacting future policies as we face increasing challenges from global environmental change."

R8: SOUTHERN

Caffrey, M., & Beavers, R. (2008). Protecting Cultural Resources in Coastal US National Parks from Climate Change. George Wright Forum, 25(2), 86-97.

"It should also not be forgotten that most cultural resources cannot be moved as Cape Hatteras Lighthouse was [in North Carolina]. This may be for practical reasons or because it is simply not economically possible to do so. The National Park Service has approximately 25 parks that contain lighthouses. It is unlikely that every lighthouse in those parks could be moved if threatened by changing environmental conditions. The National Park Service also has a number of sites of cultural significance, such as Fort Massachusetts [in Mississippi], that cannot be moved. At these sites, the National Park Service must consider a strategy of retreat with selective preservation efforts, or implement harder structures such as rock armoring or sea walls to protect vital cultural resources, as rising sea levels limit the feasibility of keeping a sand buffer along the shoreline. Hard structures will not protect Fort Massachusetts from the impact of increased temperatures and the possibility of more-intense storms that could damage its structure."

"The next decades hold a great deal of uncertainty for many cultural resources throughout the world, particularly those in the coastal zone. Those in the U.S. national park system must be protected; however, this will be a difficult task in many cases, such as that of Fort Massachusetts [in Mississippi]. A number of financial and technological hurdles that require a high degree of resourcefulness must be overcome first. Cape Hatteras Lighthouse [in North Carolina] represents an extreme example of what engineering methods can be used to protect these resources; it is also an example of managers taking a more proactive approach to planning for climate change."

SOUTH ATLANTIC

Berenfeld, M. L. (2008). Climate Change and Cultural Heritage: Local Evidence, Global Responses. The George Wright Forum, 25(2), 66-82.

"Constructed on a spit of land off the southern tip of Florida and part of Dry Tortugas National Park, Fort Jefferson is the object of a multi-year, multi-million-dollar conservation effort led by the National Park Service [Information about the restoration project can be downloaded from the NPS website: www.nps.gov/drto/upload/Restoration%20site%20bulletin4.pdf]. Fort Jefferson is endangered by exposure to salt air, rusting internal metal structures, and the eroding ground on which it was built. This building is one of many coastal historic sites in the U.S. that are threatened by rising sea levels and other threats posed by climate change, and although many sites may be protected from those threats through thoughtful conservation and maintenance, it is important that we consider the question of how to allocate resources for these efforts. Predictions about climate change impacts would seem to indicate that Fort Jefferson is likely both to experience significant further damage as a result of increasingly severe hurricanes and storms, and, by the end of the century, to be frequently flooded if not largely under water [IPCC 2007e, 630 and passim]. With sites like this in mind, the question of allocating resources must be expanded to consider new factors."

Caffrey, M., & Beavers, R. (2008). Protecting Cultural Resources in Coastal US National Parks from Climate Change. George Wright Forum, 25(2), 86-97.

"Furthermore, high-intensity hurricanes with storm surges also contributed to a large amount of erosion around the lighthouse when it was in its previous position. Some 28 recorded hurricanes have directly struck Cape Hatteras National Seashore [North Carolina] since 1854 (NOAA 2006). In 2003, Hurricane Isabel particularly impacted the barrier islands of capes Lookout and Hatteras. In particular, the IPCC has noted increased intense tropical cyclone activity in the North Atlantic since the 1970s, which is linked to increased sea-surface temperatures (IPCC 2007a). Given the expected increases in sea-surface temperatures resulting from anthropogenic warming, the IPCC (2007b) now finds it likely that intense tropical cyclone activity will increase, which could further jeopardize the Cape Hatteras coastline and its cultural resources."

"It should also be considered that many national parks still contain valuable cultural artifacts on their grounds that have not yet been discovered. Recent erosion at Jamestown National Historic Site [in Virginia] uncovered a location of significant archeological value that could have been eroded away had it not been for its discovery by park managers. There are still many sites on national park property that could be of significant cultural value to future generations but which cannot all be identified before the impacts of climate change take their toll (NPCA 2007)."

SOUTH CENTRAL

Berenfeld, M. L. (2008). Climate Change and Cultural Heritage: Local Evidence, Global Responses. The George Wright Forum, 25(2), 66-82.

"As we consider these issues [of the impacts of climate change on cultural heritage], we need only look to Louisiana for an example of such a scenario. New Orleans, which is home to one of the largest collections of historic buildings in the country, presents a case study (Figure 1, no. 7). New Orleans is not only a cautionary tale of natural disasters waiting to happen—and possibly more frequently and with greater severity as the Earth warms—it is also an example of how cultural heritage can and will be lost in those disasters if we don't prepare for them, and, how deeply that loss will be felt. Thousands of the distinctive houses of New Orleans were damaged by Hurricane Katrina, but many more have been destroyed since the storm through short-sighted demolition in the effort to clean up."

"The historic buildings of New Orleans are not simply charming for tourists and residents, however; they are also practical architectural responses to the climate—built up on piers in case of floods (of normal levels), constructed out of cypress wood that comes from the nearby swamps and is more resistant to damage caused by humidity, and made with high ceilings and windows that provide cross breezes in hot weather. Tearing down and replacing these houses with buildings that could be constructed anywhere not only destroys the character of the city and its history, but is also bad environmental strategy."

Caffrey, M., & Beavers, R. (2008). Protecting Cultural Resources in Coastal US National Parks from Climate Change. George Wright Forum, 25(2), 86-97.

"[in addition to the construction of a rock jetty around Fort Massachussets in coastal Mississippi] Soft approaches have also been taken, including dredging offshore and in channels to relocate sand back onto the national seashore's beaches, particularly on West Ship Island to renourish what has been eroded, using sediment of a similar size and composition. But this is not a permanent solution and ongoing maintenance is required. However, sea level continues to rise which, coupled with the geology of the area, will threaten Fort Massachusetts by making the structure increasingly more vulnerable to shoreline encroachment and inundation."

HUNTING AND FISHING

NATIONAL

Ficke, A. D., Myrick, C. A., & Hansen, L. J. (2007). Potential impacts of global climate change on freshwater fisheries. Rev Fish Biol Fisheries, 581-613.

"Temperate rivers will experience changes in the timing and composition of precipitation. Reduced snowpacks will decrease spring flows, especially in systems that occupy regions that are marginal with respect to snow storage (Magnuson 2002b); major rivers such as the Mississippi (USA) and the Severnaya Dvina (Russia) will be affected by the decrease in snowpack (Nijssen et al. 2001). In high latitude rivers, the expected increase in precipitation and decrease in snowpack will result in an earlier, smaller flood pulse (ACIA 2004). Without high spring flows, these stream systems may experience lower minimum flows (Nijssen et al. 2001). This could negatively affect populations of economically important fishes. For example, introduced Chinook salmon (Oncorhynchus tshawytscha) in New Zealand migrate during low-flow periods; a further decrease in stream discharge during seasonal low flows may block their migration (McDowall 1992)."

Irland, L. C., Adams, D., Alig, R., Betz, C. J., Chen, C., Hutchins, M., … & Sohngen, B.L. (2001). Assessing Socioeconomic Impacts of Climate Change on US Forests, Wood-Product Markets, and Forest Recreation. BioScience, 51(9), 753-764. doi: 10.1641/0006-3568(2001)051[0753:ASIOCC]2.0.CO;2

"Sustaining coldwater fisheries is a key issue. There is little doubt that increased temperatures will significantly reduce available trout habitat and populations (Ahn 1997). Brook trout habitat, in particular, is likely to become increasingly limited and fragmented. A study by the US Environmental Protection Agency estimated changes in consumer benefits of recreational anglers from changing water temperatures (Michaels et al. 1995). Warmer temperatures resulted in a net loss in user benefits."

Joyce, L. A., Blate, G. M., Littell, J. S., McNulty, S. G., Millar, C. I., Moser, S. C., . . . Peterson, D. L. (2008). National forests. in: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. a report by the U.S. climate change science program and the subcommittee on global change research. U.S.Environmental Protection Agency, 1-127.

"Altered stream flow patterns and warmer stream temperatures, observed trends that are projected to continue with future climate change (Regier and Meisner, 1990; Eaton and Scheller, 1996; Rahel, Keleher, and Anderson, 1996; Stewart, Cayan, and Dettinger, 2004; Barnett, Adam, and Lettenmaier, 2005; Milly, Dunne, and Vecchia, 2005), may change fishing opportunities from salmonids and other coldwater species to species that are less sensitive to warm temperatures (Keleher and Rahel, 1996; Melack et al., 1997; Ebersole, Liss, and Frissell, 2001; Mohseni, Stefan, and Eaton, 2003) and altered streamflow (Marchetti and Moyle, 2001)."

"The different growth responses of closely related fish species to increases in temperature and streamflow (Guyette and Rabeni, 1995) may enhance opportunities for species favored by some anglers."

Ramasamy, R., Swamy A. (2012). Global Warming, Climate Change and Tourism: A Review of Literature. Revista de Cultura e Turismo, 6, 72-98.

"Second, ecological shifts caused by climate change can alter not only the type of recreation, but the subsequent impact visitors [tourists] could have on the land. For example, fishing opportunities will decrease as rivers and lakes show reduced water levels (lack of snow melt). This, in turn, causes warmer waters which is deadly to many fish."

NORTH CENTRAL

Rempel, R. S. (2011). Effects of climate change on moose populations: Exploring the response horizon through biometric and systems models. Ecological Modelling, 222, 3355-3365. doi:10.1016/j.ecolmodel.2011.07.012

"From an ecosystem services perspective, hunting opportunities at the southern current extents of moose [Alces alces] distribution may decline, and the occurrence of moose may increase to the north of core moose zones."

R8: SOUTHERN

Ahn, S., de Steiguer, J., Palmquist, R., & Holmes, T. (2000). Economic analysis of the potential impact of climate change on recreational trout fishing in the southern Appalachian Mountains: An application of a nested multinomial logit model. Climatic Change, 45(3-4), 493-509. doi:10.1023/A:1005511627247

"Angler's expected welfare loss from the trout habitat loss by global warming varied from $5.63 to $53.18 for per angler per trip occasion depending on the scenarios employed in the Southern Appalachian mountains and these figures correspond to 2 to 20% of the angler's consumer surplus. Per angler mean welfare loss approximations for the entire year ranged from $285 to $2692. Mean yearly welfare loss for the entire population can be expanded using the total number of license holders in 1996 fiscal year (217239 anglers), which varied from 61 to 584 million in 1995 dollars. However, these estimated welfare figures from the model are only indicative of the value of potential effects and may not be appropriate to be used to inform policy makers without further research."

Flebbe, P. A., Roghair, L. D. & Bruggink, J. L. (2006). Spatial Modeling to Project Southern Appalachian Trout Distribution in a Warmer Climate. Transactions of the American Fisheries Society, 135(5), 1371-1382. doi: 10.1577/T05-217.1

"Although these species would probably remain viable in other parts of their ranges, loss of habitat for trout in the southern Appalachians would mean a loss of recreational opportunities and a potential loss of the unique southern Appalachian brook trout [Salvelinus fontinalis] strain (SDAFSTC 2005)."

INTERACTIONS WITH OTHER FACTORS

NATIONAL

Ramasamy, R., Swamy A. (2012). Global Warming, Climate Change and Tourism: A Review of Literature. Revista de Cultura e Turismo, 6, 72-98.

"It [survey findings of Koetse & Rietveld 2009] also revealed that global scale increase in temperature may influence patterns in tourism and skiing holidays with the associated changes in passenger transport [via climate change's impact on the transport sector]."

"Furthermore, an increased frequency of low water levels may increase costs of inland waterway transport considerably. The study [Koetse & Rietveld 2009] also found that given the nature of transport as a derived demand, trade flow patterns will be affected by climate change in the long run when climate change affects location patterns of production and consumption."

QUALITY OF RECREATIONAL EXPERIENCES

NATIONAL

Joyce, L. A., Blate, G. M., Littell, J. S., McNulty, S. G., Millar, C. I., Moser, S. C., . . . Peterson, D. L. (2008). National forests. in: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. a report by the U.S. climate change science program and the subcommittee on global change research. U.S.Environmental Protection Agency, 1-127.

"After wildfire, the quality of the recreational experience has been shown to be affected by the need to travel through a historical fire area (Englin et al., 1996) and by the past severity of fire (Vaux, Gardner, and Thomas, 1984)."

"Changes in vegetation and other ecosystem components (e.g., freshwater availability and quality) caused by droughts, insect and disease outbreaks (Rouault et al., 2006), fires, and storms may alter the aesthetics, sense of place, and other cultural services that the public values."

"The projected increases of pests and vectorborne diseases may also affect the quality of recreational experiences in NFs [National Forests]. Hard freezes in winter have been shown to kill more than 99% of pathogen populations annually (Burdon and Elmqvist, 1996; as cited in Harvell et al., 2002). The hard freezes necessary to slow the spread of insect and disease outbreaks may become less effective (Gutierrez et al., 2007)."

Ramasamy, R., Swamy A. (2012). Global Warming, Climate Change and Tourism: A Review of Literature. Revista de Cultura e Turismo, 6, 72-98.

"Tourism destinations, especially nature-based destinations, rely heavily on resources such as mountains, beaches, forests, and so forth. Some of these destinations are facing a serious reduction in attractiveness or even threats to their existence due to retreating mountain glaciers, the rise of sea level, and the redistribution of species (Tagliabue 2006; Phillips and Jones 2006; Hawkins and Porter 2003)."

Scott, D., Jones, B. & Konopek, J. (2007). Implications of climate and environmental change for nature-based tourism in the Canadian Rocky Mountains: A case study of Waterton Lakes National Park. Tourism Management, 28, 570 – 579. doi:10.1016/j.tourman.2006.04.020

"Any changes in the natural characteristics of mountain environments could negatively influence tourism by reducing the perceived attractiveness of the region's mountain parks (Elsasser & Burki, 2002; Scott, 2003; Wall, 1992). For example, drought conditions during the summer of 1988 contributed to widespread forest fires in Yellowstone National Park, which resulted in evacuations of campgrounds and seasonal visitor accommodations being closed 4 weeks earlier than normal (Franke, 2000). Total annual visits to Yellowstone in 1988 were reduced 15% (compared to 1987) and park officials estimated that the forest fires resulted in a loss of tourism-related economic benefits of US$60 million (Franke, 2000)."

R8: SOUTHERN

Brownstein, J. S., Holford, T. R., & Fish, D. (2005). Effect of climate change on Lyme disease risk in North America. EcoHealth, 2(1), 38-46. doi: 10.1007/s10393-004-0139-x

"Minimum temperature increase also results in the extension of suitability [for Ixodes scapularis, deer tick] into higher altitudes. Elevation is an important limiting factor for I. scapularis populations because it indirectly affects population establishment through its influence on the complex interaction among climate, physical factors, and biota (Schulze et al., 1984). As a result of increasing temperatures, the model predicts advancement of suitability into the southern Appalachian Mountains."

EAST

Brownstein, J. S., Holford, T. R., & Fish, D. (2005). Effect of climate change on Lyme disease risk in North America. EcoHealth, 2(1), 38-46. doi: 10.1007/s10393-004-0139-x

"Because 98% of the 2-year life cycle occurs off the host, climate should act as an essential determinant of distribution of established tick populations across North America (Fish, 1993). The effect of climate on [Ixodes scapularis, deer tick] population maintenance suggests the potential for climate change to alter the current vector distribution. Although recent emergence of Lyme disease throughout the northeastern and mid-Atlantic states has been linked to reforestation (Barbour and Fish, 1993), additional influence of environmental change can be expected considering the anticipated shifts in climate."

"Considering the effects of both greenhouse gases and sulfate aerosols [on Ixodes scapularis, deer tick], the area with suitable climate decreases by 12% in the 2020s, as retraction (24.7%) overpowers expansion (12.8%). This decrease is solely attributed to a reduction in suitable area in the U.S. (18.5%) focused in the Midwest. However, expansion does occur in both southern Canada (12.9%) and the southern U.S., including Texas, Oklahoma, and Arkansas. The 2050s reverses the trend of decreasing suitability with an increase in area of 10.3%. In the U.S., suitability returns to the Midwest, and expansion into the central states of Missouri and Kansas occurs. Extension into Canada continues with an additional 49.8% suitable area. The 2080s reveals the most pronounced effect of climate change, with a net increase in suitable area of 68.9%. Contraction of suitable area is confined to the southern states, especially Texas, Mississippi, and Florida. Encroachment continues in the central U.S., filling in previously unsuitable areas and closing the gap between southern and northern populations of I. scapularis. Canada experiences a major expansion of suitability in the 2080s, with a 212.9% increase. "

"Climate change is expected to cause a complicated redistribution of the vector [for Lyme Disease, Ixodes scapularis, deer tick], which reveals two major trends (Fig. 2). First, the redistribution is dominated by expansion. The increase in minimum temperature results in the expansion into higher latitudes, and this is explained by the inverse relationship between tick survival and the degree of subfreezing temperature exposure (Vandyk et al., 1996). This trend is clearly shown by the spreading of suitable area north into Canada."

"Second [of the 2 major trends predicted by models], climate change results in the contraction of suitable area [for Ixodes scapularis, deer tick]. Because the increase in maximum temperature yields unfavorable conditions for off-host survival of I. scapularis (Needham and Teel, 1991), we predict that this will result in the retraction of the vector from the lower latitudes of the U.S."

"Furthermore, environmental factors may also be responsible for controlling the enzootic maintenance of the Lyme disease agent, Borrelia burgdorferi. Climate change may exert an indirect effect on infection prevalence via its relationship with host species composition. Increases in temperature may result in the northward expansion of the southern hosts of I. scapularis [Ixodes scapularis, deer tick]."

Erickson, R. A., Hayhoe, K., Presley, S. M., Allen, L. J. S., Long, K. R., & Cox, S. B. (2012). Potential impacts of climate change on the ecology of dengue and its mosquito vector the Asian tiger mosquito (Aedes albopictus). Environmental Research Letters, 7(3), 034003. doi:10.1088/1748-9326/7/3/034003

"Our initial hypotheses about how climate would alter the population dynamics of the Asian tiger mosquito were partially supported by model results (figure 2). Atlanta [Georgia] and Lubbock [Texas] both saw the mosquito season increase in length for both mid and end of century simulations. However, mid-summer temperatures became too warm for [Aedes albopictus, Asian tiger mosquio] in the end of century projections, and this resulted in a bimodal abundance distribution. Moreover, by the end of the next century, the mosquito population had decreased in both Lubbock and Atlanta, primarily due to an increase in mosquito mortality rates caused by increased temperatures. Alternatively, in Chicago [Illinios], the dynamics were similar to what we had hypothesized: season length and population size increased."

"Low winter temperatures currently limit the range of this species [Aedes albopictus, Asian tiger mosquio] within North America (Swanson et al 2000, Roiz et al 2011), and cold winters currently prevent the establishment of the Asian tiger mosquito in locations such as the Northeastern USA (Andreadis 2009). Therefore, projected climate change will likely change the distribution and abundance of this species through time and space."

"While our predictions [for the impacts of climate change on Aedes albopictus, Asian tiger mosquio] were correct for Chicago, [Illinois], an unexpected shift occurred in Atlanta, [Georgia] and Lubbock, [Texas] where the dengue seasons increased in length, but peak population sizes decreased and peak numbers shifted to a spring and fall peak rather than a summer peak. The impactions of climate change on the Asian tiger mosquito also impacted the dynamics of dengue in an unpredicted, but similar fashion. This finding supports the general hypothesis that climate change will shift, rather than expand the spatial range of some diseases (Lafferty 2009a)."

"To complicate matters further [beyond changes due to increased temperatures], the way in which changes in precipitation as a consequence of climate change will translate into changes in mosquito habitat are unclear. Not only will the amount of precipitation likely change, but the frequencies and patterns of precipitation will likely change as well. These changes will interact with changes in temperature to impact both evaporation and relative humidity. However, studies directly assessing the impacts of these aspects of moisture availability on various mosquito life history characteristics are lacking."

Irland, L. C., Adams, D., Alig, R., Betz, C. J., Chen, C., Hutchins, M., … & Sohngen, B.L. (2001). Assessing Socioeconomic Impacts of Climate Change on US Forests, Wood-Product Markets, and Forest Recreation. BioScience, 51(9), 753-764. doi: 10.1641/0006-3568(2001)051[0753:ASIOCC]2.0.CO;2

"In mountainous landscapes (such as the Great Smoky Mountains National Park), where scenery and sightseeing are prominent attractions, warmer lowland temperatures will tend to attract more people to the relatively cooler higher elevations. Yet climate change could affect haze and could diminish the vividness of fall foliage and color displays (Bloomfield and Hamburg 1997)."

WATER RECREATION

NATIONAL

Joyce, L. A., Blate, G. M., Littell, J. S., McNulty, S. G., Millar, C. I., Moser, S. C., . . . Peterson, D. L. (2008). National forests. in: Preliminary review of adaptation options for climate-sensitive ecosystems and resources. a report by the U.S. climate change science program and the subcommittee on global change research. U.S.Environmental Protection Agency, 1-127.

"The projected reductions in volume of free-flowing streams during summer months, due to advances in the timing of flow in these streams (Stewart, Cayan, and Dettinger, 2004; Barnett, Adam, and Lettenmaier, 2005; Milly, Dunne, and Vecchia, 2005), may also restrict canoeing, rafting, and kayaking opportunities (Irland et al., 2001)."

Ramasamy, R., Swamy A. (2012). Global Warming, Climate Change and Tourism: A Review of Literature. Revista de Cultura e Turismo, 6, 72-98.

"Changes in weather patterns suggest more severe weather causing inland waterways to swell over their banks more frequently. This will negatively impact fisheries and wetland habitats and cause changes in recreation use on waterways."

RESOURCE AREA (FACTOR): LAND USE & PLANNING

ROAD AND FACILITY PLANNING

NATIONAL

Chinowsky, P. S., Price, J. C., & Neumann, J. E. (2013). Assessment of climate change adaptation costs for the US road network. Global Environmental Change, in press, 10p. doi:10.1016/j.gloenvcha.2013.03.004

"The literature includes a limited number of studies that assess climate change impacts and adaptation costs specific to roads. The Transportation Research Board (TRB) (2008) developed a detailed accounting of the potential impacts of climate change for North American roads, bridges, ports, and other transportation infrastructure. The impacts identified by the Transportation Research Board include more frequent buckling of pavement due to increased temperatures, more frequent road washouts from increases in intense precipitation events, reduced snow removal costs associated with rising temperatures in cold regions, and the settling and subsidence of roads from thawing permafrost in Alaska. Mills and Andrey (2002) identify a similar range of climate sensitivities for transportation systems and also note that climate change may affect mobility, the efficiency of the transportation system, and transportation demand."

"Overall, we estimate [using a conservative estimate of 1°C increase in temperatures by 2070 to estimate climate-related changes in road maitnence costs] that adaptation costs will be substantially higher for paved roads than unpaved roads. This result is not unexpected, as paved roads make up approximately 70% of the U.S. road network and are affected by more climate stressors than unpaved roads. The adaptation costs for paved roads largely reflect the costs associated with upgrading asphalt to higher grade binders as temperatures rise. To illustrate this point, Fig. 4 shows the relative magnitude of adaptation costs associated with re-sealing paved roads more frequently (due to precipitation and freeze–thaw effects), upgrading pavement binders, and re-shaping unpaved roads more frequently. As shown in the exhibit, binder upgrades represent the vast majority of costs across all Census Divisions and scenarios. This is consistent with the widespread temperature increases expected under both climate scenarios and suggests that the most costly adaptations for paved roads will involve changes in road design rather than maintenance."

"The results [using a conservative estimate of 1°C increase in temperatures by 2070 to estimate climate-related changes in road maintenance costs] in Fig. 4 also show that climate change is expected to lead to a reduction in routine re-sealing costs. This reflects the impact of increased temperatures on freeze–thaw cycles. With warmer temperatures, many areas are expected to transition from moderate freeze areas, where freeze–thaw effects are worst, to low freeze areas, which will significantly reduce rutting and allow transport agencies to re-seal less frequently."

"In addition to informing transportation planning, the results presented above [using a conservative estimate of 1°C increase in temperatures by 2070 to estimate climate-related changes in road maintenance costs] may help inform policy-makers of the potential benefits of the greenhouse gas mitigation policies reflected under the Global Action scenario. As our results indicate, adaptation costs are significantly lower under the Global Action scenario than under the business as usual case. In 2025, adaptation costs for paved and unpaved roads combined are approximately $65 million lower, in present value terms (3% discount rate), under the Global Action scenario relative to business as usual, which represents an 8% differential. This figure grows to $280 million in 2050 and $325 million in 2075 (56% differential)."

"Overall, the analysis [using a conservative estimate of 1°C increase in temperatures by 2070 to estimate climate-related changes in road maintenance costs] estimates an increase in the cost of building and maintaining the U.S. road network, but some costs could decline [such as re-sealing costs] as highlighted in Fig. 4."

R8: SOUTHERN

Chinowsky, P. S., Price, J. C., & Neumann, J. E. (2013). Assessment of climate change adaptation costs for the US road network. Global Environmental Change, in press, 10p. doi:10.1016/j.gloenvcha.2013.03.004

"The U.S. Climate Change Science Program (CCSP) (2008) estimates the effects of inundation from relative sea level rise (SLR) for transportation infrastructure along the coast of the Gulf of Mexico. The study concludes that, with a relative sea level rise of up to 1.2 m, 27% of the major roads in the region, 9% of rail lines, and 72% of ports are currently at or below 122 cm in elevation, although portions of these assets are currently guarded by protective structures, such as levees and dikes. The study also examined the potential for short-term flooding associated with a 5.5- and a 7.0-m storm surge and found that more than half of the Central Gulf Coast's major highway infrastructure is subject to temporary flooding. "